BRAZING

IN

SPACE –

The next frontier…

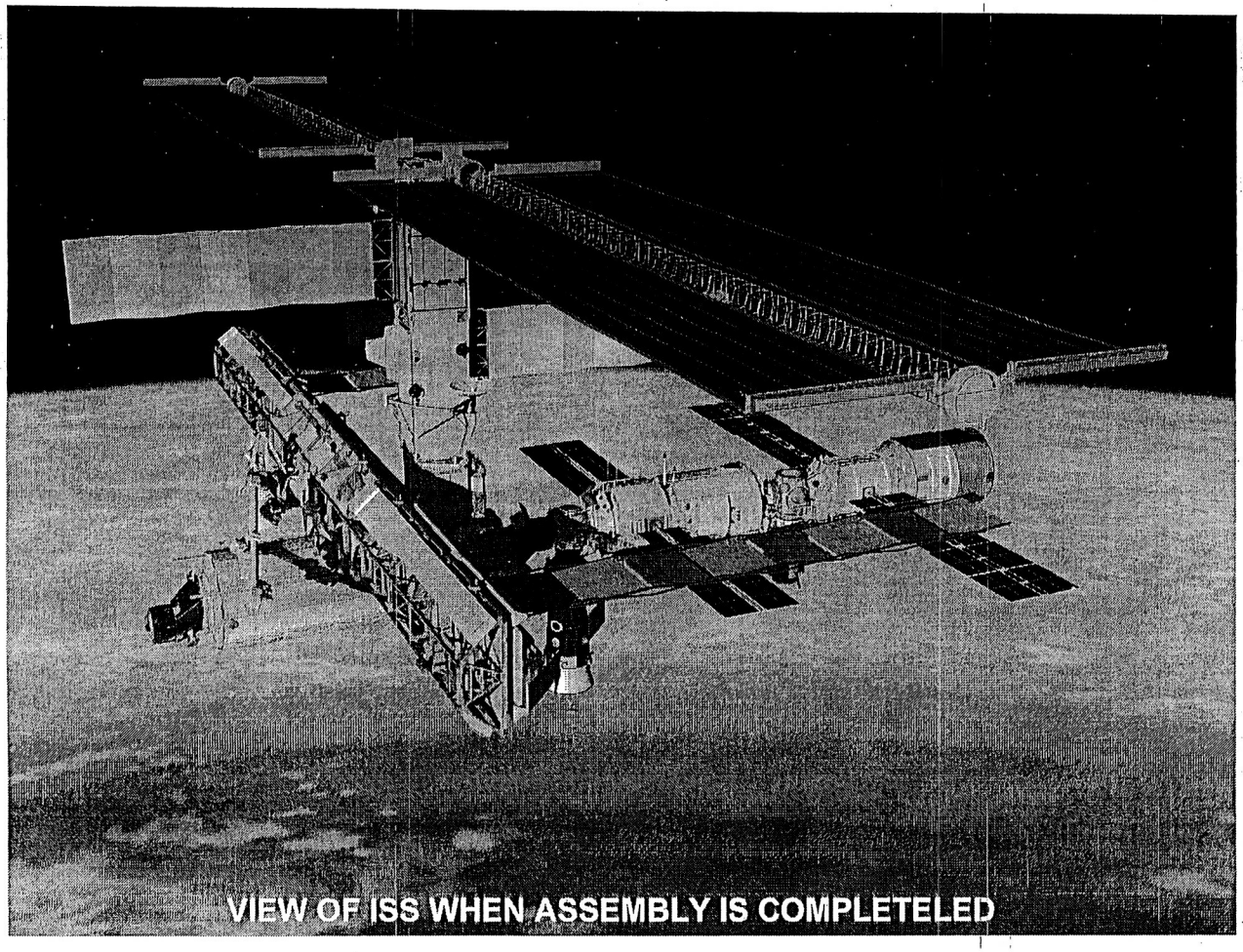
BRAZING IN SPACE

OUTLINE

- WHY DO WE NEED TO JOIN COMPONENTS IN SPACE
- WHY BRAZING?
- HISTORY OF BRAZING IN SPACE
- ELECTRON BEAM VACUUM BRAZING
- CURRENT EFFORT AT GSFC
- FUTURE WORK

BRAZING IN SPACE

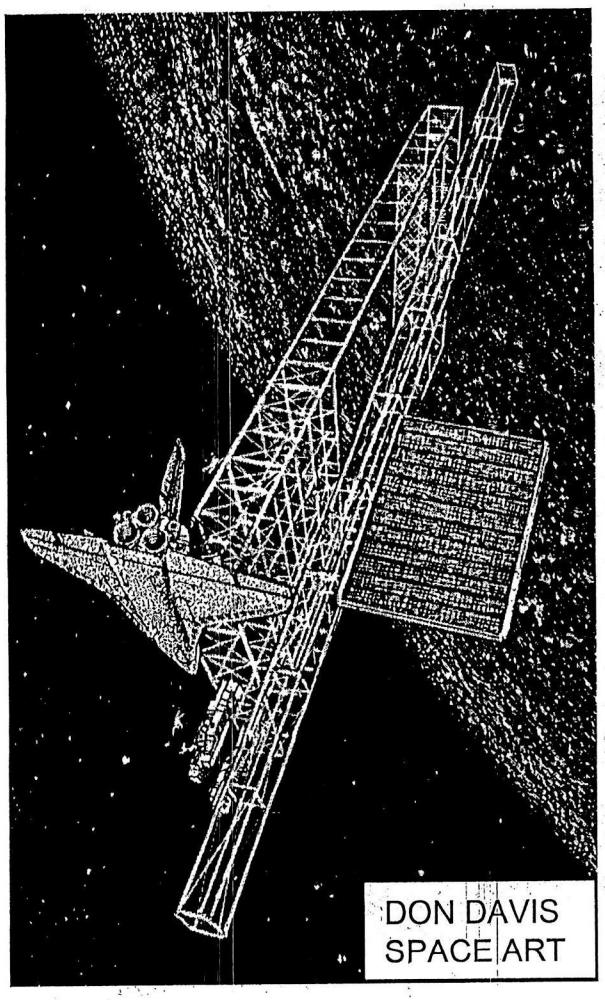
- ***WHY DO WE NEED TO JOIN COMPONENTS IN SPACE***

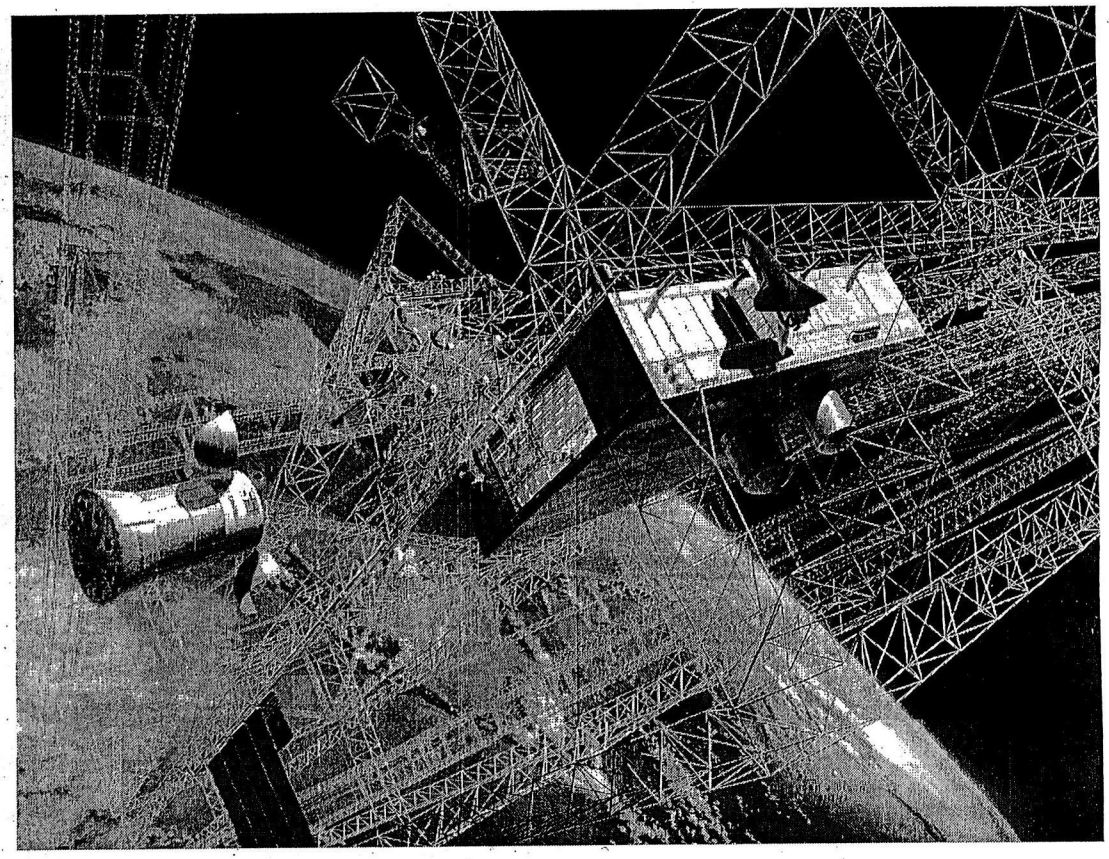


VIEW OF ISS WHEN ASSEMBLY IS COMPLETELED

BRAZING IN SPACE

- ***WHY DO WE NEED TO JOIN COMPONENTS IN SPACE***





BOEING VISION OF ON-ORBIT CONSTRUCTION SITE FOR SPS

BRAZING IN SPACE

•WHY DO WE NEED TO JOIN COMPONENTS IN SPACE

- In-space assembly can enable the deployment of large systems that cannot be accommodated in current or near-term launch vehicle payload provisions, whether limited by total mass, volume, density, or mission criticality.

- Risk mitigation and failure-intervention provisions, both for mission objectives and for humans space flight support, can be more readily accommodated on an assembly mission than on a build-and-deploy mission

BRAZING IN SPACE

- ***WHY DO WE NEED TO JOIN COMPONENTS IN SPACE***

A DRAWING OF HUMANS AND ADVANCED ROBOTIC ASSISTANTS BUILDING A SPACE TELESCOPE,

NASA, The Vision for Space Exploration, Feb. 2004

"As for the future, your task is not to see it, but to enable it"

Antoine de-Saint Exupery

BRAZING IN SPACE

- ***WHY BRAZING ?***

STRUCTURAL JOINING PROCESSES:

- **MECHANICAL JOINING**
- **WELDING**
- **ADHESIVE BONDING**
- **BRAZING**

BRAZING IN SPACE

•WHY BRAZING ?

- **NO SINGLE METHOD CAN SATISFY ALL JOINING NEEDS IN SPACE**

- **SELECTION OF JOINING METHOD DEPENDS ON:**

  - **APPLICATION**
  - **TYPE OF STRUCTURE**
  - **MATERIALS**

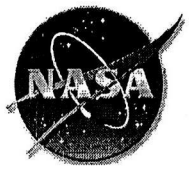
BRAZING IN SPACE

- ***WHY BRAZING ?***

OUR FOCUS IS ON CONSTRUCTION OF LARGE TRUSS STRUCTURES IN SPACE:

- **TEDEIOUS AND SLOW PROCESS;**
- **CONSISTS OF A LARGE QUANTITY OF REPETATIVE STEPS;**
- **REQUIRES PERMANENT JOINTS**

BRAZING IN SPACE



•WHY BRAZING ?

SPACE IS A NATURAL ENVIRONMENT FOR VACUUM BRAZING:

- no extra cost is required to create vacuum!
- does not depend on gravity - relies on capillary action
- molten metal is drawn into the joint interface
- joins any shape and any wall thickness
- generates no debris or fumes

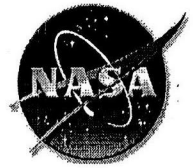
BRAZING IN SPACE

- ***WHY BRAZING ?***

.... AND THE WINNER IS ...ELECTRON BEAM VACUUM BRAZING!

- ELECTRON BEAM IS A VERY FLEXIBLE, HIGHLY CONTROLLED METHOD OF DELIVERING PRECISE AMOUNT OF ENERGY TO A SPECIFIC LOCATION – BEAM CAN BE DEFLECTED, CHANGE SPOT SIZE, ACCELERATION VOLTAGE, PULSING, ROTATION – ALL BEAM MANIPULATIONS CAN BE DONE ELECTRONICALLY, I.E. NO MECHANICAL MOVEMENT IS REQUIRED!
- ELECTRON BEAM GUN IS A MATURE TECHNOLOGY, IDEALLY SUITED FOR SPACE ENVIRONMENT!
- IT HAS BEEN SUCCESSFULLY USED IN SPACE FOR WELDING, BRAZING, CUTTING AND METAL VAPOR DEPOSITION BY THE RUSSIAN COSMONAUTS.
- TRADE-OFF ANALYSIS SHOWS THAT EB BRAZING IS A BETTER CHOICE THAN LASER, RESISTANCE, INDUCTION OR EXOTHERMIC PROCESS

BRAZING IN SPACE

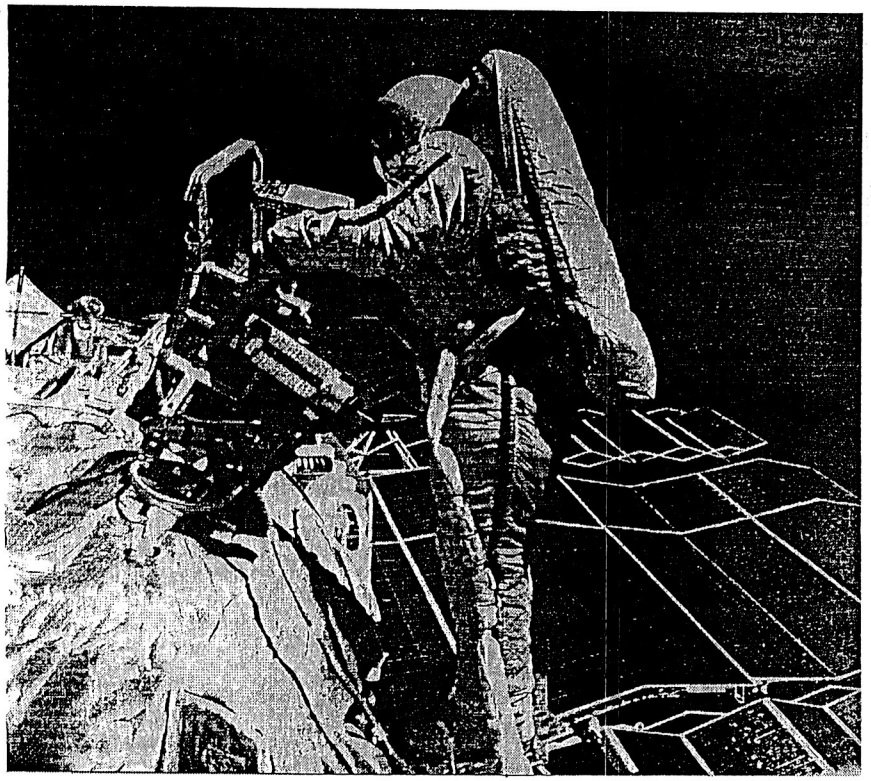


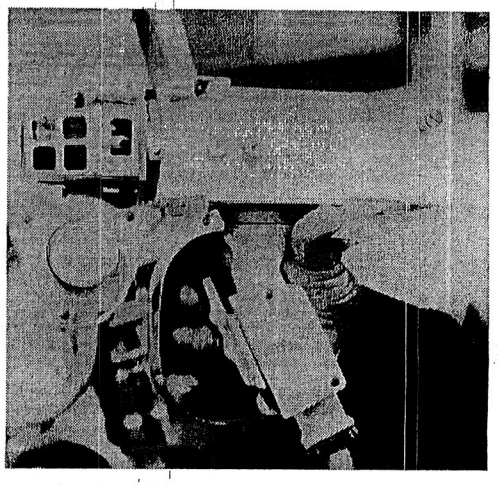
- ***BRAZING EXPERIENCE IN SPACE***

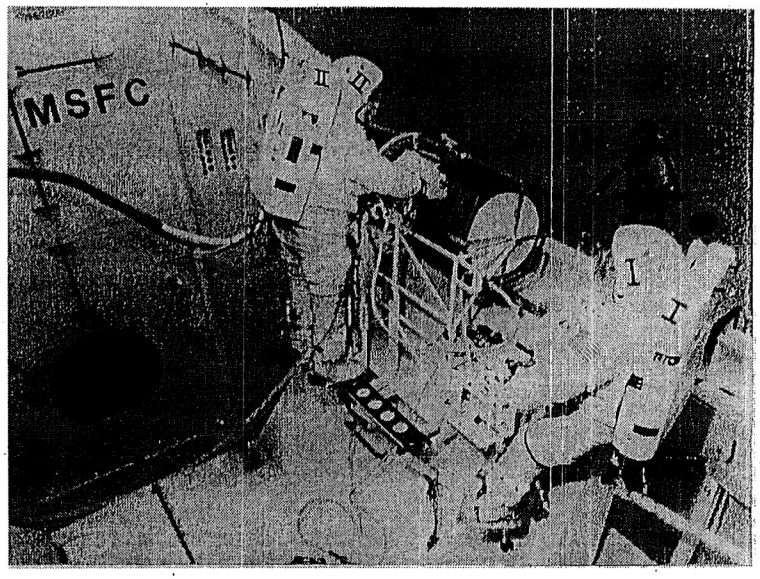
PLATFORM	MATERIALS BRAZED	BRAZE ALLOY	HEAT SOURCE	COMMENTS
Skylab Station, USA, 1973	Pure nickel tubes and sleeves, 304L stainless steel tubes and sleeves.	AWS BAg8a (71.8%Ag, 28% Cu and 0.2% Li)	Exothermic reaction	Excellent filler metal flow. Nice fillet formation. **0-g helps capillary action.**
TEXUS II sounding rocket, Germany, 1978	Pure nickel cylinders	58%Ag, 39%Cu, 3% Li	Isothermal furnace	Extremely wide gaps of up to 2 mm could be filled under **microgravity owing to capillary forces.**
STS-9, Launch # 9, Columbia, USA, 1983	Nickel cylinders	AWS BAg8a	Isothermal Heating Facility	Microstructure was found to be independent on the gravitational level.
Solyut 7 Space station, USSR, 1984 - 1986	Thin wall nickel chromium alloy tubing plated with Ni to promote wetting.	Low melting alloy Sn-2Ni-4Ge developed at Paton Welding Institute.	Hand held Universal Electron Beam Gun	Good wetting and formation of fillets. After melting, pre-placed filler metal did not flow outside the joint gap. Much wider gaps can be filled under 0-g.
TR-IA sounding rocket, flight # 5, Japan, 1996	Stainless steel sleeves	Ag-Cu-Li alloy	Multipurpose furnace	Samples were subjected to isothermal and temperature gradient conditions. All joints showed complete penetration under microgravity. **Future plans include additional metallurgical studies to develop basic data for structural construction in space.**

BRAZING IN SPACE

- ***BRAZING EXPERIENCE IN SPACE***



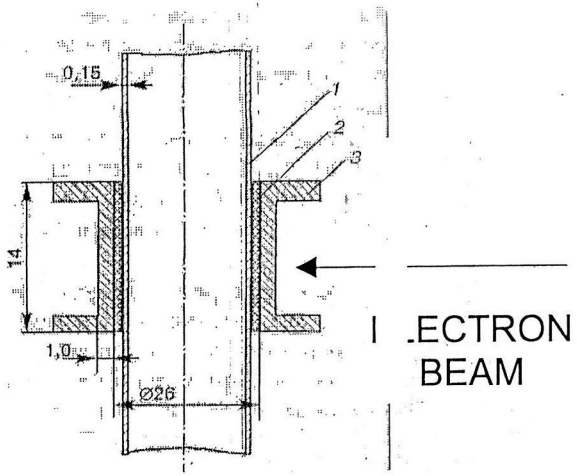


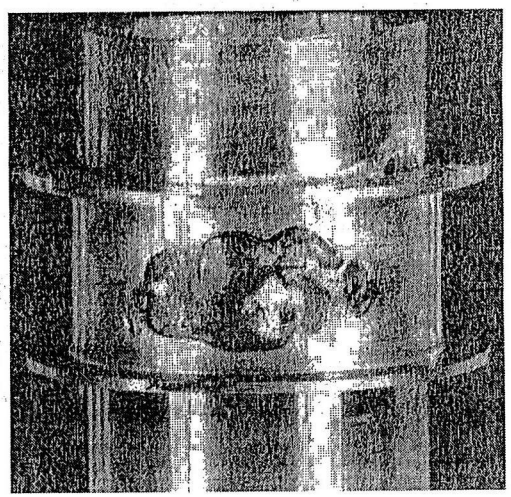


BRAZING IN SPACE

- ***BRAZING EXPERIENCE IN SPACE***

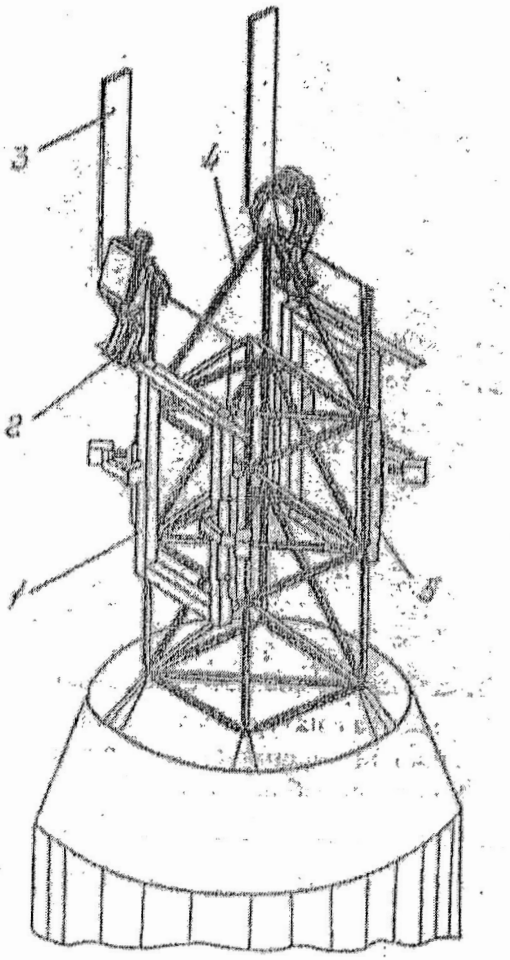
ELECTRON BEAM VACUUM BRAZING EXPERIMENT WAS PERFORMED QUITE SUCCESSFULLY BY THE RUSSIAN COSMONAUTS IN OPEN SPACE ON SALYUT-7 IN 1986.

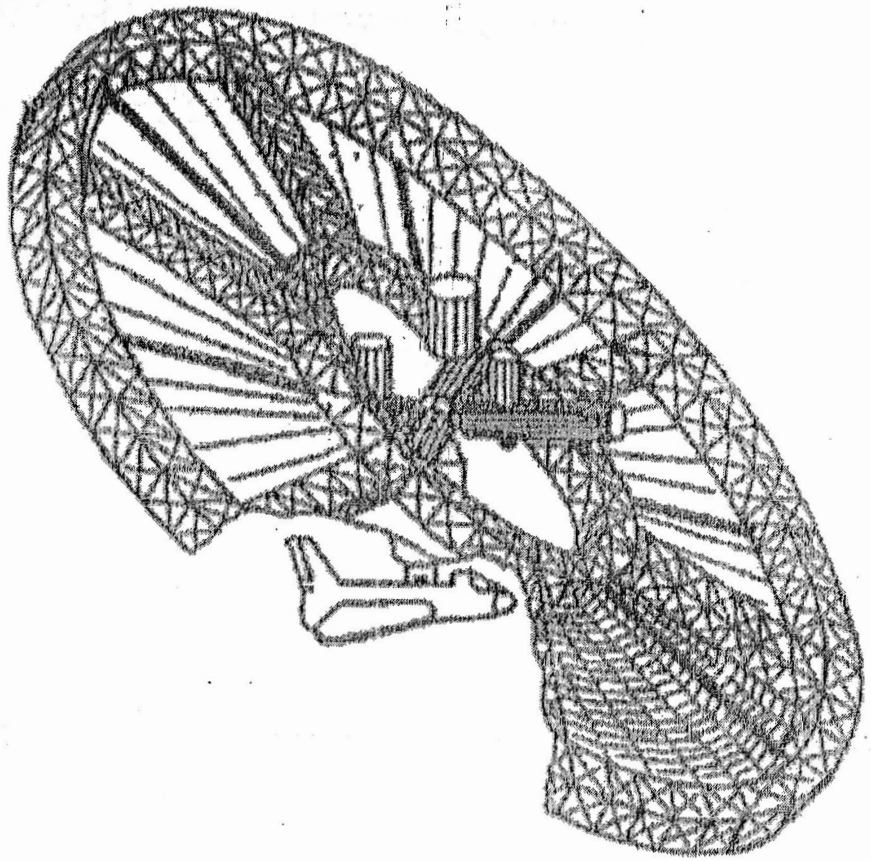




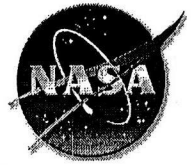
BRAZING IN SPACE

- ***BRAZING EXPERIENCE IN SPACE – CONSTRUCTION OF "MIR-2"***





BRAZING IN SPACE



- ***ONGOING EFFORT AT GODDARD***

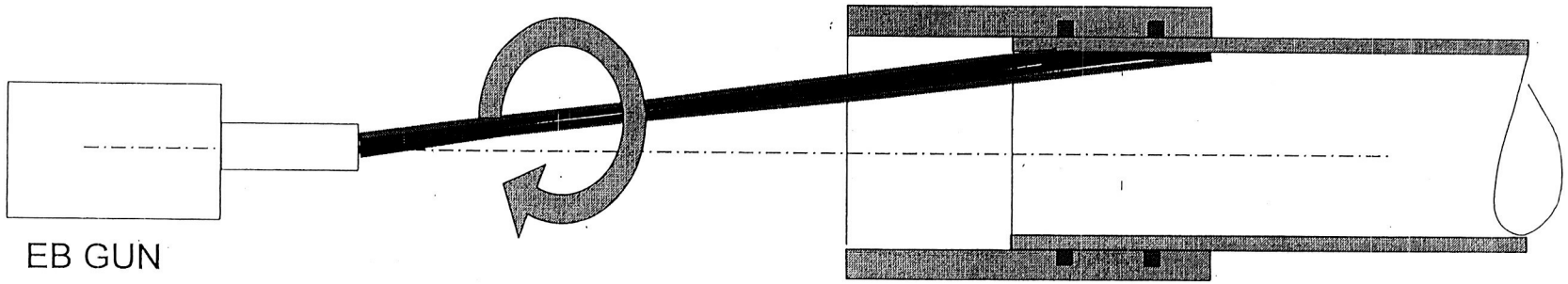
IN-SPACE ROBOTIC INTEGRATION SYSYTEM (IRIS)

(initiated in 2005)

- **BRAZING PROCESS**
- **BRAZEABLE TRUSS STRUCTURE**
- **AUTOMATION**

BRAZING IN SPACE

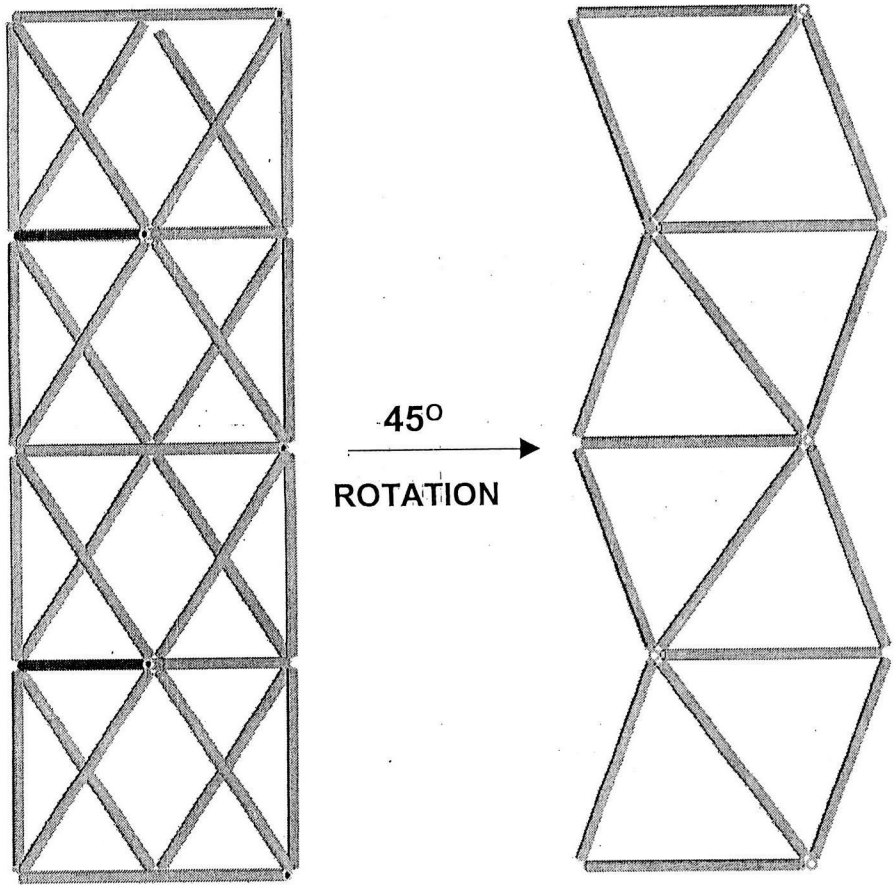
- ***EFFORT AT GODDARD – brazing process***



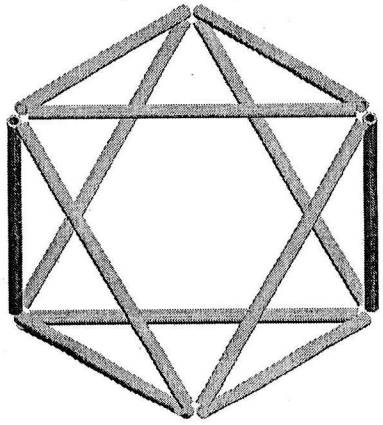
ROTATING ELECTRON BEAM IS APPLIED TO THE INTERNAL SURFACE OF THE BRAZE JOINT

BRAZING IN SPACE

- ***EFFORT AT GODDARD – brazeable truss structure***



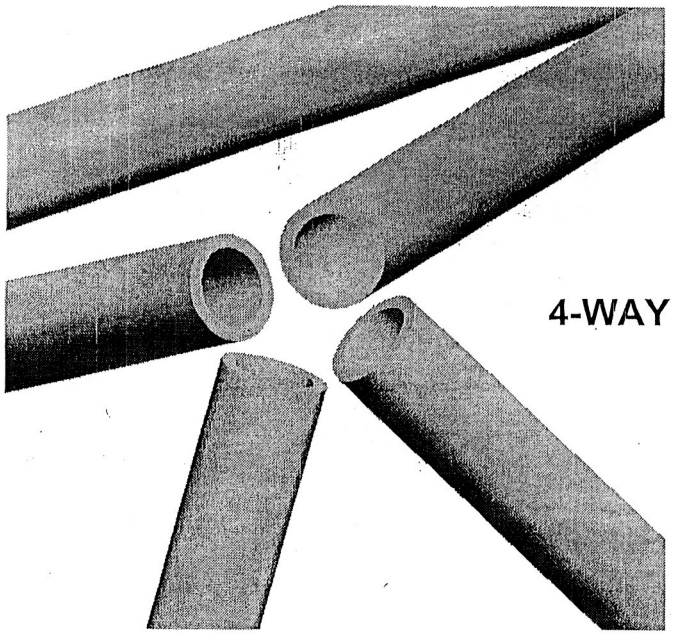
EXAMPLE OF BRAZEABLE TRIANGULAR TRUSS



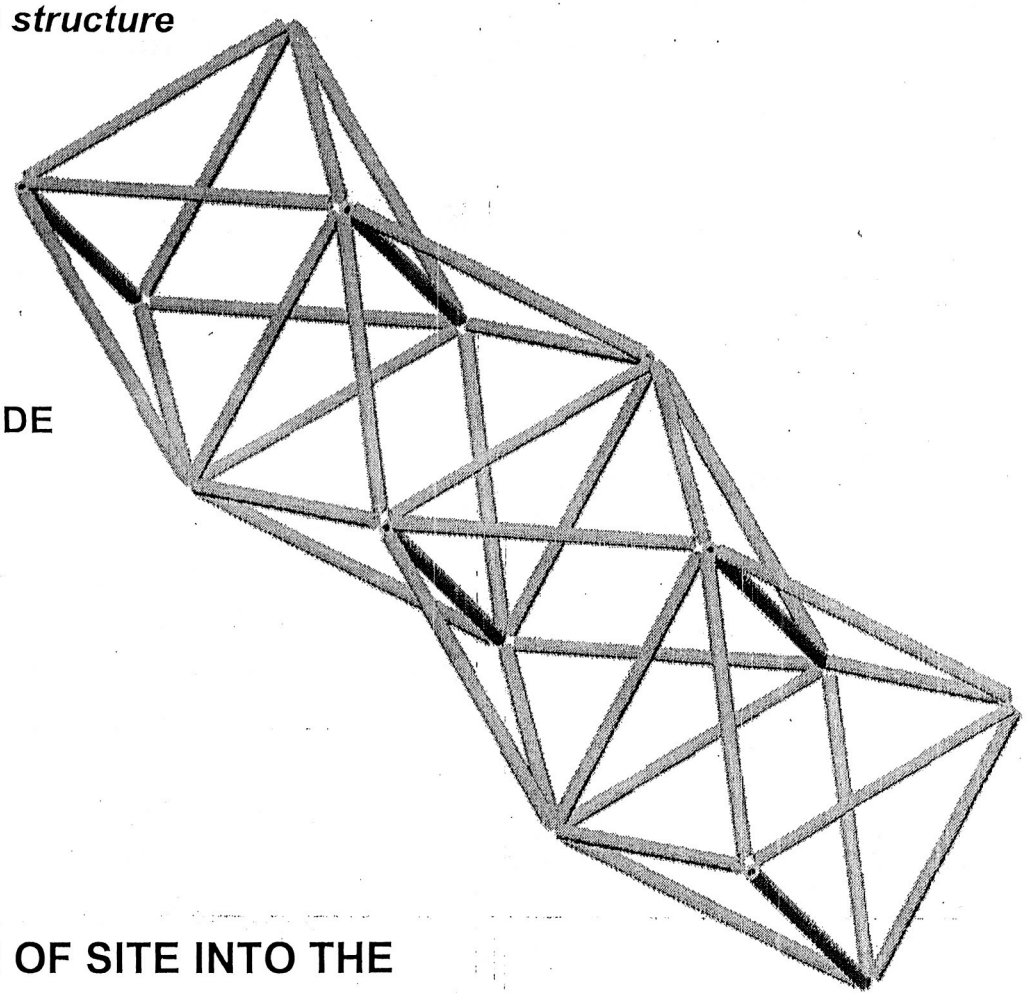
TOP VIEW

BRAZING IN SPACE

- ***EFFORT AT GODDARD – brazeable truss structure***



4-WAY NODE

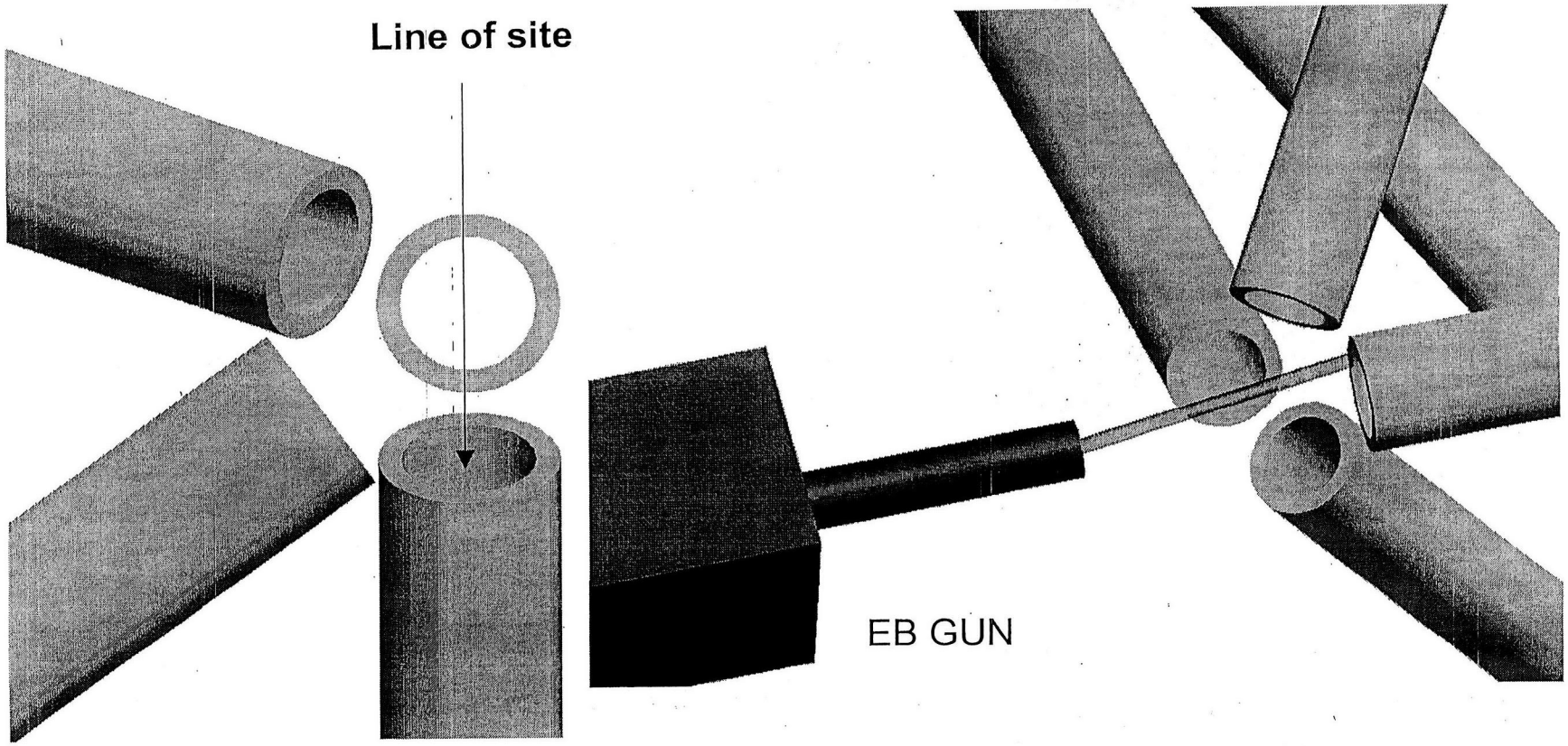


ADVANTAGE OF THIS DESIGN:

PROVIDES UNOBSTRACTED LINE OF SITE INTO THE TUBULAR STRUT

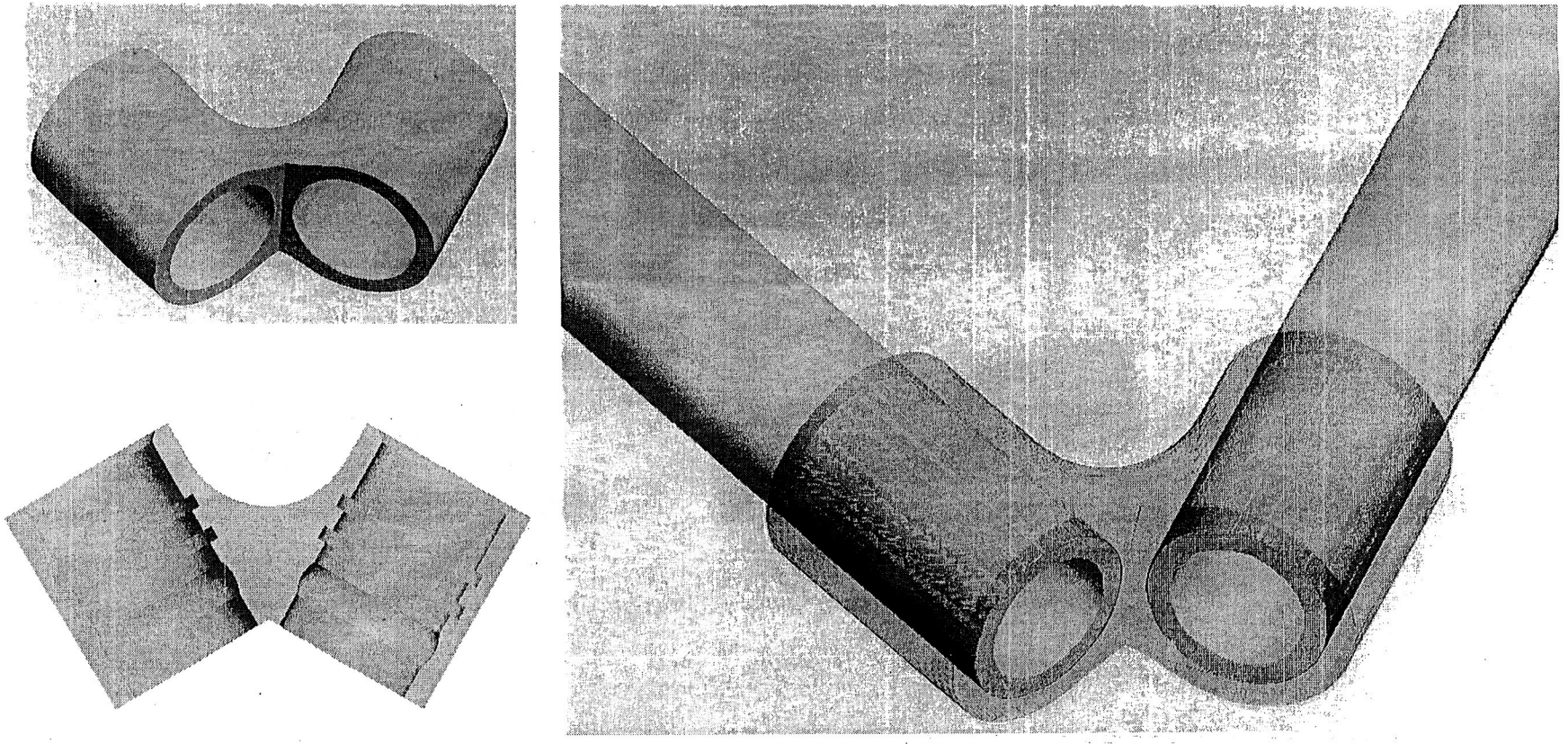
BRAZING IN SPACE

- ***EFFORT AT GODDARD – brazeable truss structure***



BRAZING IN SPACE

- ***EFFORT AT GODDARD – brazeable truss structure***

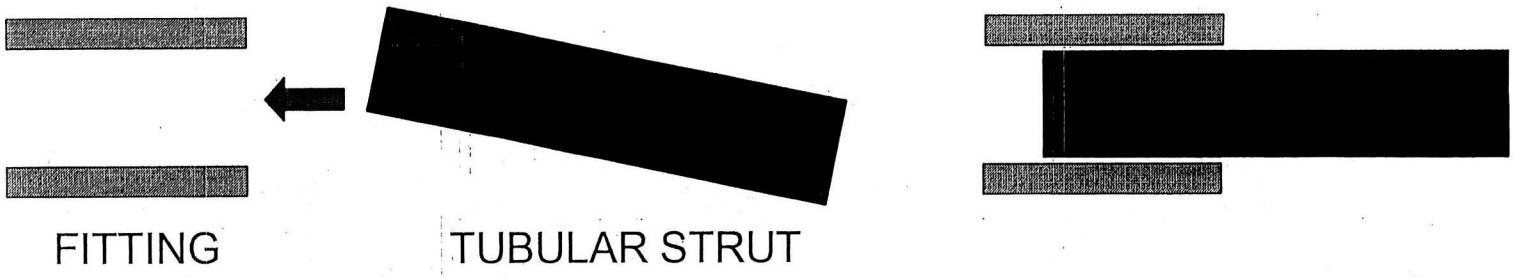


EXAMPLE OF 2-WAY "OPEN" FITTING

BRAZING IN SPACE

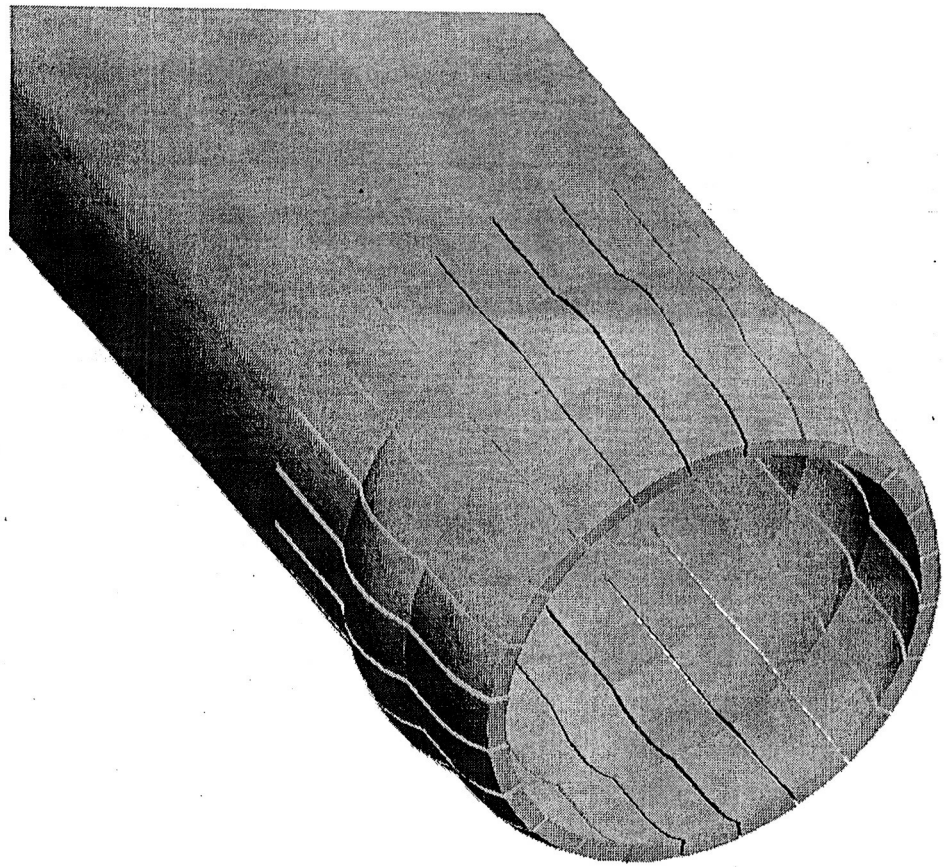
- ***EFFORT AT GODDARD – robotics***

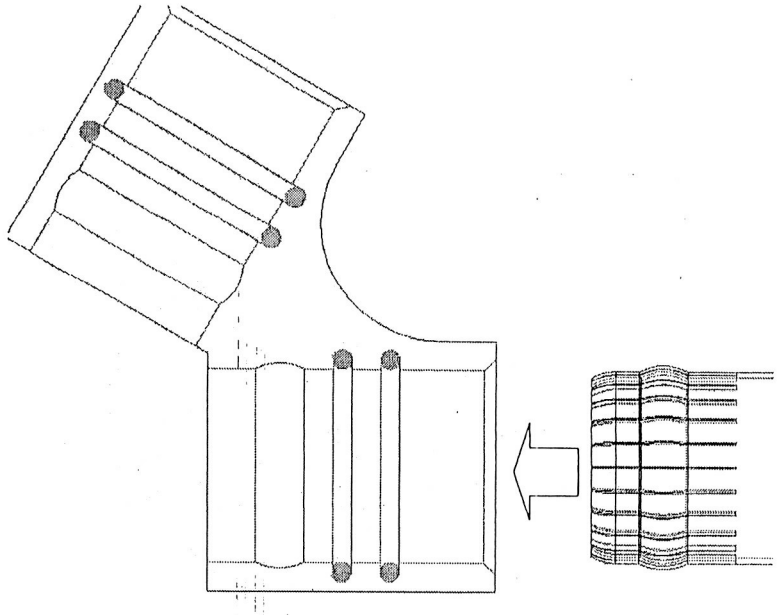
MAJOR CHALLENGE – ROBOTIC PRECISION POSITIONING



BRAZING IN SPACE

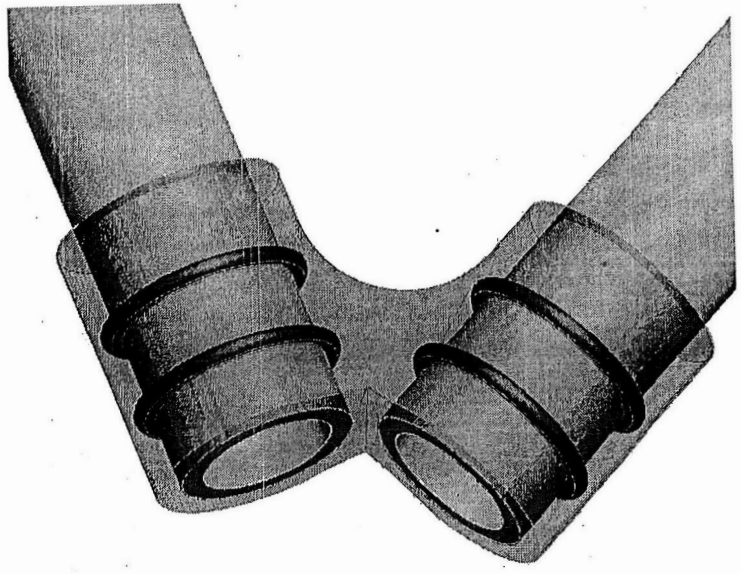
- ***EFFORT AT GODDARD – robotics***

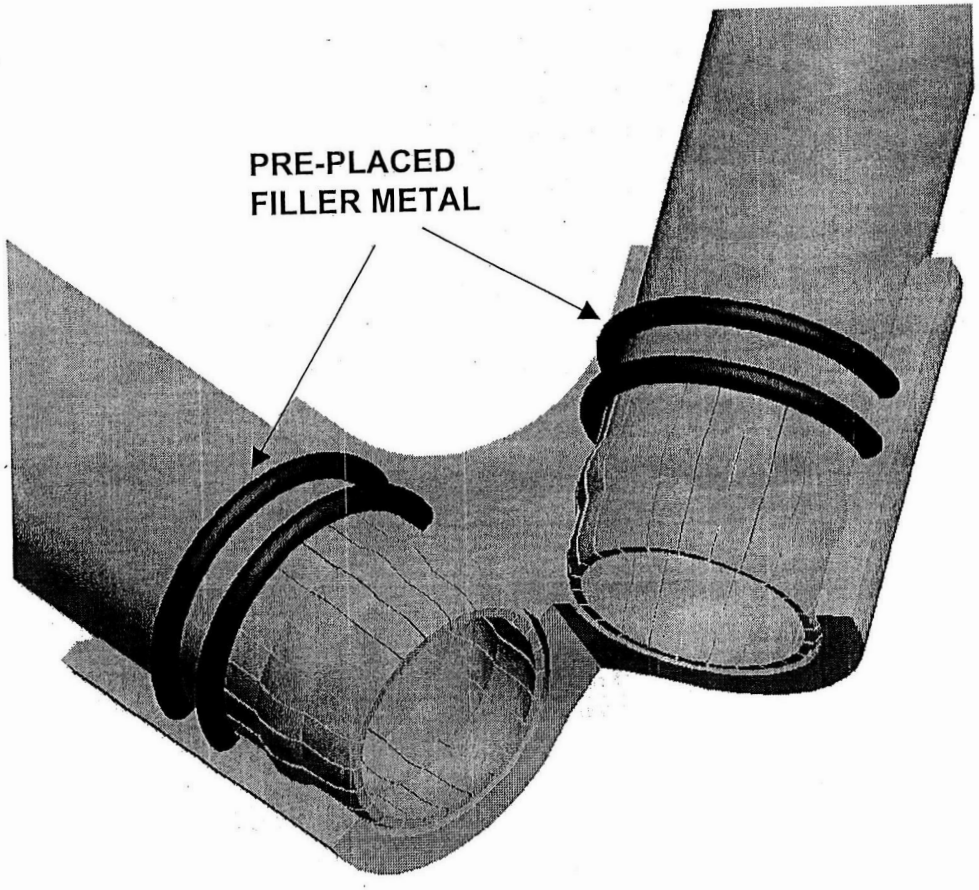




BRAZING IN SPACE

- ***EFFORT AT GODDARD – brazeable assembly***





2-WAY NODE ASSEMBLY SHOWING THE BRAZE JOINTS READY FOR BRAZING